INNOVATIVE TECHNOLOGY
Summary Report

# Commercial Three-Step Technology for Decontamination of Gloveboxes

Deactivation and Decommissioning Focus Area

*Prepared for*
U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

June 2003

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Summary Report

# Commercial Three-Step Technology for Decontamination of Gloveboxes

OST/TMS ID xxxx
LAUR 03-2182

Deactivation and Decommissioning Focus Area

*Demonstrated at*
Los Alamos National Laboratory
Los Alamos, New Mexico

# INNOVATIVE TECHNOLOGY
Summary Report

## Purpose of this Document

Innovative Technology Summary Reports (ITSR) are designed to provide potential users with sufficient information to quickly determine whether a technology would apply to a particular environmental management problem.

The purpose of an ITSR is to describe a technology or process that has been developed and tested with funding from the U.S. Department of Energy's (DOE) Office of Science and Technology (OST). Each report presents the full range of application for the technology or process and the advantages to DOE in terms of technology performance, cost, and effectiveness. Most reports include comparisons to baseline and/or competing technologies. Information about commercial availability and technology readiness for implementation is also included. ITSRs are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published ITSRs are available on the OST Web site at http://apps.em.doe.gov/ost/itsrall.asp.

## TABLE OF CONTENTS

SECTION 1
# SUMMARY

## Technology Summary

The DOE continually seeks effective and safer decontamination technologies for use in decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology sponsors large scale Demonstration and Development Projects (LSDDP) in which developers and vendors of improved and innovative technologies showcase products that are potentially beneficial to DOE projects and to others in the D&D community. Benefits sought include reducing health and safety risks to personnel and the environment, increasing productivity, and decreasing the cost of operation.

The demonstration described in this ITSR was conducted at Los Alamos National Laboratory (LANL) to quantitatively evaluate the performance of the Environmental Alternatives Inc. (EAI) commercial three-step technology for removal of plutonium contamination from gloveboxes. Removal of this contamination will allow for gloveboxes to either be reused or classified as low-level waste (LLW). The decontamination technique involves the application of proprietary solutions onto the metallic surfaces of the glovebox. The radiological contaminants are removed by spraying the solution onto the surface, scrubbing it with an abrasive pad, and wiping with rags. Depending on the initial surface activity, several applications may be required to reduce contamination from the category of transuranic (TRU) waste to LLW.

The demonstration at LANL included comparison of the EAI technology to the baseline technique (nitric acid solution) in use at LANL. As a baseline for the demonstration, a traditional chemical means of decontaminating gloveboxes was used that involved wiping down the glovebox surfaces with rags soaked in a dilute acid solution to dissolve and remove actinides from the surfaces. This method has been used for many years at LANL and other DOE sites to decontaminate gloveboxes. In general, this technique requires several applications to reduce the contamination from TRU to LLW levels.

Figure 1 provides a photograph of the glovebox during the EAI technology demonstration. Figure 2 shows the method used to measure the surface activity after each decontamination cycle.

**Figure 1. Photograph of Glovebox Floor during Decontamination Demonstration**

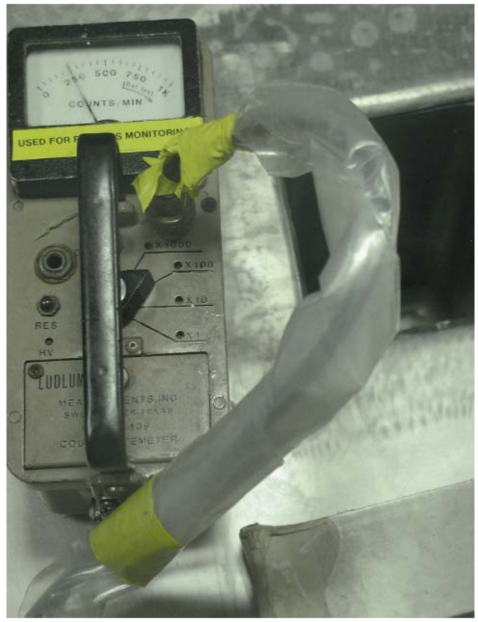


**Figure 2. Surface Activity Measurements**

Note that this innovative technology was used extensively at the Rocky Flats Environmental Technology Site for glovebox decontamination. A purpose of this demonstration was to quantify the technology performance on a side-by-side environment relative to the baseline technology currently in use at LANL.

## Problem

The LANL waste inventory includes approximately 200 “legacy” TRU waste gloveboxes in temporary storage in Technical Area 54 (TA-54). These gloveboxes will be processed through the LANL Decontamination and Volume Reduction System to separate the LLW and TRU waste components. The separated LLW will be disposed of in the LLW disposal area at TA-54. The TRU waste will be packaged and certified for disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

Waste items/components classified as TRU waste are costly to dispose, with an estimated cost of approximately $140,000 for an average sized glovebox. If the LANL gloveboxes can be decontaminated to LLW (i.e., < 100 nanocuries per gram [nCi/g] of long-lived radioisotopes) the disposal cost will be reduced to approximately $6,500. In addition to cost savings, decontamination may enable the reuse of gloveboxes that are not considered obsolete by design.

## How It Works

The EAI decontamination technology requires applying and removing (by rinsing) three separate chemical formulations to the contaminated surfaces in a specified sequence. Each formulation is customized based on the metal to be decontaminated and the isotopes present. Each formulation is applied in low volumes, usually as a spray, left to set for a defined time, rinsed clean, and then removed. The technology is not dependent on adequately scrubbing the surface to be effective. The application and removal of all three formulations (and associated rinsing) to the contaminated surfaces consists of one cycle of the process, and typically requires one day (24 hours) to complete. This cycle is repeated as needed until the desired residual decontamination levels are achieved.

The EAI solutions are reportedly compatible with all glovebox surfaces including windows and plastic seals and gaskets.

The solutions do not contain chemicals that would result in classification of the spent material as hazardous waste under the Resource Conservation and Recovery Act. As a result, the technology does not produce a “mixed” waste stream and liquid and solid wastes therefore can be characterized as TRU or LLW based on the radiological properties and concentrations of the contaminants.

## Demonstration Summary

The EAI decontamination technology was demonstrated at LANL in September 2002 at the Plutonium Facility located at TA-55 of the Los Alamos National Laboratory using an established and approved test plan. The demonstration was conducted on active gloveboxes that are to be decontaminated for re-use in the same location. The demonstration included the application of the EAI solution formulations (as directed by EAI technical representatives) to all of the interior surfaces of a glovebox with a total area of 11.1 m$^2$ (119 ft$^2$). Prior to conducting the demonstration, the inner surfaces of the glovebox were wiped with Fantastik™, a commercial household cleaner. All points measured on the glovebox surfaces showed a total alpha activity above one million counts per minute, which translates to 2,857 kilo disintegrations per minute [kdpm]/100 cm$^2$ when the instrument efficiency is applied.

The baseline technology, nitric acid wipe down, was used on one half of a similar glovebox to develop comparable data. The demonstration was executed according to the Test Plan without any significant disruptions or issues. Data was taken according to the plan and measurements showed the progress of the decontamination. The operation times from start to finish of each task, alpha survey measurements for surface activity, and waste volumes generated during the demonstration were recorded.

## Results

The surface activity that LANL uses to meet their LLW disposal site requirements is 50 kdpm/100 cm$^2$. The decontamination process is expected to be continued until this objective is met.

The EAI Decontamination Technology produced the following key results:

EAI decontamination (Innovative technology)

- Two workers decontaminated the 11.1 m$^2$ (119 ft$^2$) glovebox to the desired survey level working approximatley 12 hours on the glovebox over a three-day period. Three cycles of decontamination were conducted using the EAI technology to reach the desired contamination levels. Additional effort was necessary to initially characterize the glovebox and perform waste packaging after the decontamination was complete.
- The initial decontamintion cycle resultined in a decontamination factor (DF) of 25. Subsequent spot decontaminations resulted in an overall DF of 1.5 and 1.3 for these cycles. The average surface activity over the entire surface of the glovebox was reduced to 49 kdpm/100 cm$^2$.
- The demonstration produced approximately 0.028 m$^3$ (1 ft$^3$) of waste.
- The unit cost for EAI decontamination was \$3,095/m$^2$ (\$288/ft$^2$) for this demonstration. In a production environment the cost would be reduced due to improved efficiencies.

Nitric acid decontamination (Baseline technology)

- Two workers decontaminated ½ of a glovebox (5.1 m$^2$ [54.9 ft$^2$]) working approximatley 6.6 hours on the glovebox. Two cycles of decontamination were conducted, but it was estimated that two additional cycles would be required to achieve the decontamination goal. Additional effort was necessary to initially characterize the glovebox and perform waste packaging after the decontamination was complete.
- Nitric acid solution reduced the overall actvitiy of the portion of the glovebox treated, but did not succeed in reducing the contamination level to below 50 kdpm/100 cm$^2$ at some survey locations after two decontamination cycles. A drop in surface activity over the entire surface for each decontamination cycle was a DF of 2.3 resulted in an average of 257 kdpm/100 cm$^2$.
- The nitric acid decontamination resulted in a waste volume of 0.18 m$^3$ (6.36 ft$^3$).
- The unit cost for the four-cycle nitric acid decontamination of the baseline glovebox was \$2,875/m$^2$ (\$267/ft$^2$).

## Contacts

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All published Innovative Technology Summary Reports are available on the Office of Science and Technology (OST) Web site at http://www.apps.em.doe.gov/ost/itsrall.html. The Technology Management System (TMS), available at http://tms.em.doe.gov, provides information about OST programs, technologies, and problems.

The Los Alamos LSDDP website address is: http://www-emtd.lanl.gov/LSDDP/DDtech.html.

SECTION 2
# TECHNOLOGY DESCRIPTION

## Overall Process Definition/Technology Definition

Innovative Technology

The proprietary EAI chemical extraction process employs as many as 25 different components in four separate chemical formulations, used in combination to accomplish the extraction of contaminants. Two of the formulations are surface preparation formulas (0300 and 0200) that contain complex blends of acids and other chemical agents to clean dirt, oil, grease and other interferences from the surface. These blends solubilize inorganic and organic chemicals and prepare the substrate by establishing proper conditions for the extraction step.

The extraction blend (0100) uses the chemical properties of micro emulsification and chemical ion exchange to extract contaminated media from the surface of the glovebox. When applied, the extraction blend penetrates below the surface and binds itself to the contaminants, then pulls the contaminants horizontally and vertically through the microscopic pores to the surface. Additional components of the formula encapsulate the contaminants to prevent recontaminating the surface, keeping them in suspension until they can be removed during the rinse step. A final formulation (0400) is used in situations where extra solvency is desirable. EAI also supplies a rinse solution to be used following each step. Note that the chemicals may be applied in a different order, depending on the application.

Baseline Technology

The baseline technology for this demonstration consists of wiping down the glovebox surfaces with a dilute nitric solution. This method has been shown to dissolve the contamination layer covering the base metal, and eventually a part of the base metal. The rags used to apply this technology are most often polypropylene rags. In most cases, the technology can be applied as many times as needed to achieve the desired level of contamination.

One disadvantage of this technology is that many rags are used resulting in a large volume of secondary waste. Another disadvantage is that excess toxic reagents become hazardous waste.

## System Operation

Innovative Technology

The EAI process consists of applying and rinsing three chemical solutions in the correct sequence and combinations to achieve optimal contamination removal. The chemical solutions are applied in low volumes, usually as a spray, to minimize consumption and secondary waste volume. After being applied, the chemical solutions are scrubbed into the contaminated surfaces, allowed to react for a specified amount of time, and then rinsed and removed. The application and removal of one or a combination of solutions constitutes one cycle of the process and typically requires one day (24 hours) to complete. Sampling and/or surveys can be performed at the end of any cycle, and often show a 90 percent reduction in contamination.

EAI representatives delivered solutions in premixed marked spray bottles, with Scotch-Brite pads, squeegees, extension rods, and polypropylene rags. LANL TA-55 technicians carried out the application of the chemicals and decontamination activities. The EAI technicians remained available during the demonstration to answer questions and resolve problems as they occurred. The method prescribed by EAI for the LANL glovebox included applying the 0100 solution, the 0200/0300 solution followed by the 0300 solution with associated intermediate rinses.

## Baseline Technology

The baseline technology is applied by vigorously wiping down the glovebox surfaces with plastic rags wetted with 0.5 normal (N) nitric acid solution. It is important to use many rags to prevent contaminants from spreading to previously decontaminated areas. When complete, the rags are placed in a bag and removed from the glovebox.

SECTION 3
**PERFORMANCE**

## Demonstration Plan

### Background/Site Description

Innovative Technology

The demonstration was conducted at TA-55 using a glovebox that has been in service for about 17 years and was used to carry out analytical chemistry functions involving actinide solutions in nitric, oxalic, and hydrofluoric acid. The test glovebox measured 2.4 m (96 in) long, 1.1 m (45 in) high and 0.76 m (30 in) deep and is constructed of 4.8 mm (3/16 inch) thick 316L stainless steel (Figure 3). The surface area of all inner surfaces totals approximately 11.1 $m^2$ (119 $ft^2$). The glovebox included three viewing windows on the front wall measuring 0.52 m (20½ in) by 0.29 m (11½ in), and three chest windows measuring 14 cm (5½ in) by 24 cm (9¼ in) each. The 12 gloveports on the glovebox face were each 15 cm (6 in) in diameter and contained Hypalon 15 mil gloves on the lower stations, and 60 mil gloves on the upper stations. The glovebox also included a shelf on the back wall that was decontaminated during the demonstration. The equipment for the demonstration was introduced into this glovebox through 0.48 m (19 in) doors located on the right and left sides. The glovebox environment was dry air.


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**Figure 3. Demonstration Glovebox**

Baseline Technology

Due to compatibility issues between the EAI technology solutions and dilute nitric acid, a separate glovebox was utilized for demonstration of the baseline technology. For the demonstration, the baseline technology was applied to one-half of a similar glovebox.

A picture showing the inner surfaces of the glovebox used for this baseline technology demonstration is shown in Figure 4. The areas of the inner surfaces of the glovebox may be seen in Table 1. This glovebox is 316 stainless steel and has leaded glass windows. The front of the glovebox includes six 15 cm (6 in) gloveports, three viewing windows, and three smaller windows that are located between the gloveports. Equipment is introduced into the glovebox through a 36 cm (14 in) opening on the left side. A dropbox connects to the left side that is connected to a trolley system that allows materials to be introduced into the glovebox line, and moved between gloveboxes in the facility. The glovebox environment is argon.

**Figure 4. Glovebox left and right internal surfaces (Note: shelves on back wall were removed for the demonstration)**

| Glovebox Surface | Area m$^2$ (ft$^2$) |
|---|---|
| Floor | 1.09 (11.7) |
| Front | 0.97 (10.4) |
| Back Wall | 1.30 (14.0) |
| Ceiling | 0.87 (9.4) |
| Side Wall | 0.87 (9.4) |
| **Total** | **5.10 (54.9)** |

**Table 1. Baseline Technology Demonstration Glovebox Surface Areas**

**Objectives**

The goal of this demonstration was to evaluate the EAI decontamination technology based on its ability to achieve the following objectives:

- Improved Decontamination Performance – The ability to remove radioactive contamination from the glovebox surface to such a level that that it could be recycled, reused, or disposed of as LLW. For this demonstration 50 kdpm/100 cm$^2$ was used as the decontamination objective for all points on the glovebox.

- Increase Feasibility – Due to the large surface area to decontaminate, the ability to not be labor intensive, difficult to handle, or difficult to automate.

- Safety – The innovative technology should not result in contamination of workers or an increased exposure time to radioactive hazards.

- Waste Minimization – The method should not create large quantities of secondary waste. Any waste generated must have a path forward to disposal (i.e., LLW, TRU or Mixed TRU).

- Cost-Effectiveness – The method should not give rise to costs which would exceed the costs for waste treatment and disposal of the material without decontamination.

**Procedure**

Data collected during the demonstration included alpha activity before and after each decontamination cycle, labor hours to mobilize, labor hours to apply and remove the solutions, labor hours to demobilize, the volume of acid solutions used, and the number of rags necessary to complete the demonstration.

### Baseline Technology

A technician prepared 1 liter (L) of 0.5N nitric acid solution and introduced the solution and polypropylene rags into the glovebox line. All surfaces on half of the glovebox were wiped down and then surveyed for remaining total alpha activity. This process was repeated so that three data points could be collected. After the work was finished, the rags were put into a bag, and the bottle containing the dilute acid solution was moved to an adjacent glovebox and bagged out as liquid waste. For the demonstration, the data collected consists of work hours to mobilize, apply, and demobilize the technology. Also recorded were the volume of acid solution used and the volume of rags necessary to complete this phase of the demonstration.

### Innovative Technology

Prior to the demonstration, the inner surfaces of the innovative technology demonstration glovebox were wiped down with Fantastic™ to remove dirt and other residues. The surfaces were surveyed at various locations for total alpha contamination, using an air proportioned alpha probe to establish an initial surface activity. Approximately 97% of the interior of the demonstration glovebox surfaces showed alpha activity above 2,857 kdpm/100 $cm^2$. A Ludlum Model 139 Survey Meter with Model 43-32 Air Proportional Detector was used to measure the alpha activity following each decontamination cycle for both the innovative and baseline technologies.

The EAI technology was demonstrated using up to three cycles of decontamination to reach the decontamination goals. Some areas did not require three cycles.

The following is the typical decontamination sequence. Variations in this sequence are used to achieve optimal contamination removal:

- Decontamination Cycle I

    1. Survey the glovebox surfaces to be decontaminated to establish an initial surface activity.
    2. Spray the EAI 0100 solution onto the surfaces and scrub using an abrasive pad.
    3. Leave the solution on the surface for 20 minutes.
    4. Rinse using the EAI rinsate solution.
    5. Remove the solution and rinsate using a squeegee and rags to wipe up the liquid waste.
    6. Spray the EAI 0200/0300-solution mixture onto the surfaces and scrub using an abrasive pad.
    7. Leave the solution on the surface for 20 minutes.
    8. Rinse using the EAI rinsate solution.
    9. Remove the solution and rinsate using a squeegee and rags to wipe up the liquid.
    10. Spray the EAI 0300 solution onto the surfaces and scrub using an abrasive pad.
    11. Leave the solution on the surface for 20 minutes.
    12. Rinse using the EAI rinsate solution.
    13. Remove the solution and rinsate using a squeegee and rags to wipe up the liquid.
    14. Re-survey to determine the residual surface activity.

- Decontamination Cycle II

    1. Spray the EAI 0100 solution onto the surfaces and scrub using an abrasive pad.

    2. Leave the solution on the surface for approximately 600 minutes.

    3. Rinse using the EAI rinsate solution.

    4. Remove the solution and rinsate using a squeegee and rags to wipe up the liquid waste.

    5. Re-survey to determine the residual contamination level.

- Decontamination Cycle III

    1. Spray the EAI 0100 solution onto the surfaces and scrub using an abrasive pad.

    2. Leave the solution on the surface for 20 minutes.

    3. Rinse using the EAI rinsate solution.

    4. Remove the solution and rinsate using a squeegee and rags to wipe up the liquid.

    5. Spray the EAI 0200/0300-solution mixture onto the surfaces and scrub using an abrasive pad.

    6. Leave the solution on the surface for approximately 600 minutes.

    7. Rinse using the EAI rinsate solution.

    8. Remove the solution and rinsate using a squeegee and rags to wipe up the liquid.

    9. Re-survey to determine the residual surface activity.

## Results

Baseline Technology

The result of the baseline technology decontamination is shown in Table 2. An average drop in surface activity was calculated for the nitric acid solution demonstration and resulted in a drop from 1,343 kdpm/100 $cm^2$ to 257 kdpm/100 $cm^2$. Each decontamination cycle resulted in a decontamination factor of 2.3.

| Glovebox Surface | Surface Activity (kdpm/100 $cm^2$) | | |
|---|---|---|---|
| | **Initial** | **Cycle 1** | **Cycle 2** |
| Back Wall | 1,429 | 429 | 57 |
| Right Wall | 714 | 286 | 143 |
| Ceiling | 286 | 186 | 29 |
| Front Wall | 1,429 | 215 | 57 |
| Floor | >2,857 | 1,786 | 1,000 |
| **Glovebox Ave** | 1,343 | 580 | 257 |
| **DF** | | **2.3** | **2.3** |

**Table 2. Results – Nitric Acid Decontamination Cycles**

Figure 5 provides a graph that shows the drop in surface activity for each survey location associated with the nitric acid decontamination cycles.

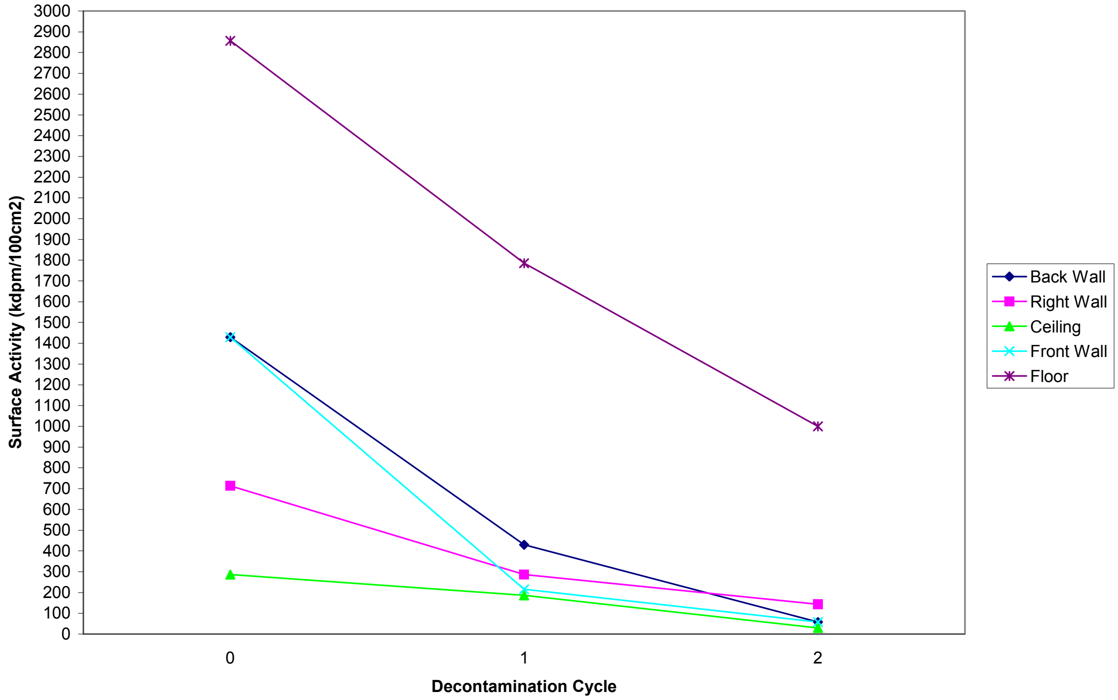


**Figure 5. Decontamination Results for Nitric Acid Solution**

Even after the second wiping, each surface of the glovebox, except the ceiling, was still above the target level of 50,000 dpm/100cm$^2$. For the baseline to reach this target level of decontamination, most of the glovebox surfaces would need to be wiped at least one or two more times and the floor would need to be wiped at least three more times. To account for this additional effort, it is assumed that the entire glovebox would need to be wiped the equivalent of two more times.

<u>Innovative Technology</u>

Table 3 provides the surface activity results for the EAI technology decontamination cycles. The technology reduced the average contamination in the glovebox to less then 50 kdpm/100 cm$^2$. The first cycle of decontamination resulted in a decontamination factor of approximately 25. This was most likely due to the removal of remaining loose contamination and contamination embedded in the upper most oxidized layer of the glovebox surface. The remaining decontamination cycles resulted in a decontamination factor from 1.3 to 1.5.

| Surface | Surface Activity (kdpm/100 $cm^2$) | | | |
|---|---|---|---|---|
| | **Initial** | **Cycle 1** | **Cycle 2** | **Cycle 3** |
| Left Floor Back | >2,857 | 100 | 71 | 71 |
| Left Floor Front | >2,857 | 286 | 43 | 43 |
| Center Floor Back | >2,857 | 214 | 157 | 157 |
| Center Floor Front | >2,857 | 286 | 257 | 21 |
| Right Floor Back | >2,857 | 57 | 63 | 63 |
| Right Floor Front | >2,857 | 286 | 214 | 6 |
| **Floor Average** | >2,857 | **205** | **134** | **60** |
| Left Wall | >2,857 | 57 | 14 | 14 |
| Right Wall | >2,857 | 171 | 36 | 36 |
| Left Wall Front | >2,857 | 71 | 57 | 57 |
| Center Wall Front | >2,857 | 100 | 63 | 63 |
| Right Wall Front | >2,857 | 100 | 36 | 36 |
| Left Wall Back | 2,714 | 21 | 21 | 21 |
| Center Wall Back | 857 | 43 | 29 | 29 |
| Right Wall Back | 2,143 | 43 | 23 | 23 |
| Center Shelf | >2,857 | 214 | 157 | 157 |
| Left Shelf | >2,857 | 214 | 86 | 86 |
| Right Shelf | >2,857 | 186 | 86 | 86 |
| **Wall Average** | **2,597** | **111** | **55** | **55** |
| Left Window | 2,857 | 17 | 29 | 29 |
| Center Window | 571 | 17 | 14 | 14 |
| Right Window | 214 | 13 | 10 | 10 |
| Upper Left Window | >2,857 | 29 | 29 | 29 |
| Upper Center Window | >2,857 | 29 | 29 | 29 |
| Upper Right Window | >2,857 | 43 | 43 | 43 |
| Lower Left Widow | >2,857 | 100 | 100 | 100 |
| Lower Center Window | >2,857 | 57 | 57 | 57 |
| Lower Right Window | >2,857 | 11 | 11 | 11 |
| **Window Average** | **2,310** | **35** | **36** | **36** |
| Left Ceiling | 2,714 | 57 | 57 | 57 |
| Center Ceiling | 857 | 43 | 43 | 43 |
| Right Ceiling | 2,143 | 43 | 43 | 43 |
| **Ceiling Average** | **1,905** | **48** | **48** | **48** |
| **Glovebox Average** | **2,490** | **100** | **65** | **49** |
| **DF** | | **25** | **1.5** | **1.3** |

**Table 3. Results – EAI Technology Decontamination Cycles**

Figure 6 provides a graph that shows the drop in average surface activity for each glovebox surface decontaminated during the EAI technology demonstration.

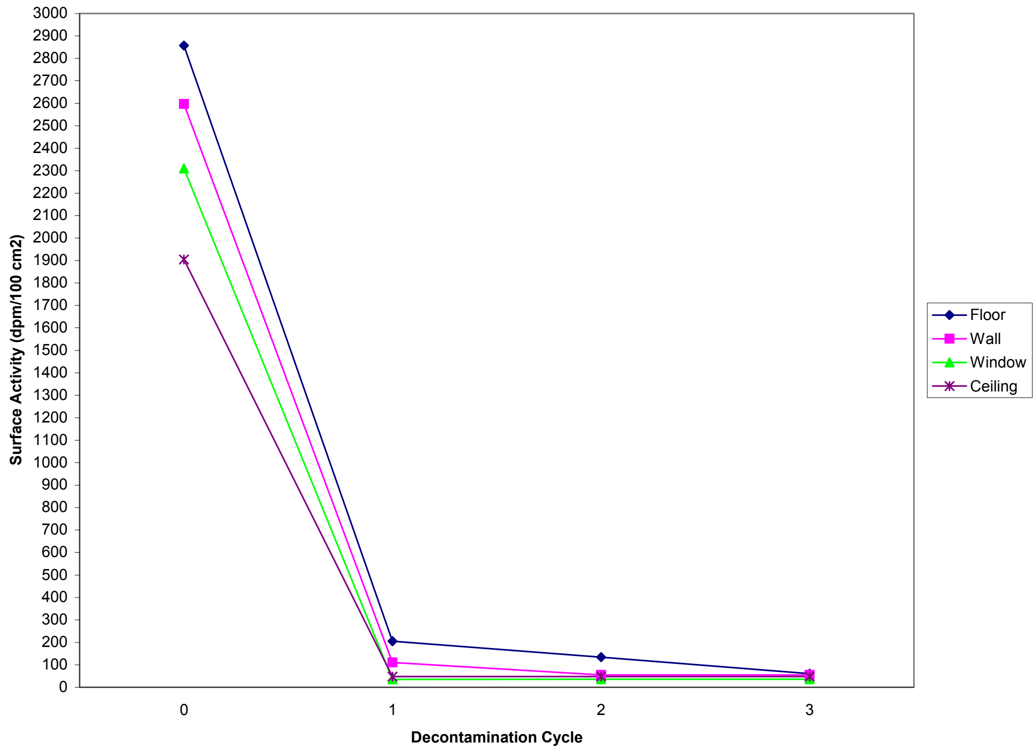


**Figure 6. Decontamination Results for EAI decontamination**

An average drop in surface activity was calculated for the EAI technology demonstration and resulted in a drop from 2,857 kdpm/100 cm$^2$ to 49 kdpm/100 cm$^2$.

Table 4 provides a breakdown of the time expended to complete each task during the demonstration. It was estimated that a total of 2 additional cycles would be necessary to achieve 50 kdpm/100 cm2 for any single survey point using the nitric acid technique. The table totals have been adjusted to include the time necessary to complete these cycles and have been extrapolated to include the time necessary to complete an entire glovebox.

| Activity | Time (hour) | | | |
|---|---|---|---|---|
| | EAI Technology | Nitric Acid Baseline Technology | | |
| | (3 cycles)[a] | (1/2 glovebox, 1 cycle)[a] | (whole glovebox)[b] | (4 cycles)[b] |
| Initial Survey | 1 | 0.5 | 1 | 1 |
| Prepare solutions and introduce into Glovebox | 1 | 3 | 3 | 6 |
| Apply and Scrub | 4 | 0.5 | 1 | 4 |
| Rinse and Dry | 5 | | | |
| Post-decontamination Surveys | 3 | 0.33 | 0.66 | 2.6 |
| Waste Packaging | 8 | 0.75 | 1.5 | 6 |
| **Total** | 22[c] | | | 19.6[d] |
| **Unitized (hr/m$^2$)** | 2.0 | | | 1.9 |

a Total for all decontamination cycles conducted during the demonstration
b Extrapolated
c Surface Area Decontaminated = 11.1 m$^2$ (119 ft$^2$)
d Surface Area Assumed Decontaminated = 2 x 5.1 m$^2$ = 10.2 m$^2$ (110 ft$^2$)

**Table 4. Recorded Times for EAI and Nitric Acid Demonstrations**

Table 5 provides a list all of the waste produced during the demonstration and shows the extrapolation necessary to estimate the effort required to perform an adequate baseline technology application to a whole glovebox of approximately the same size.

| Waste Description | Decontamination Solution and Waste Quantities | | | |
|---|---|---|---|---|
| | EAI Technology | Nitric Acid Baseline Technology | | |
| | (3 cycles)[a] | (1/2 glovebox, 2 cycles)[a] | (whole glovebox)[b] | (4 cycles)[b] |
| Decontamination Solution | 4,000 mL | 1,000 mL | 2,000 mL | 4,000 mL |
| Abrasive Pads (Scotch-Brite) | 8 | 0 | 0 | 0 |
| Polypropylene Rags | 85 rags | 10 bags | 20 bags | 80 bags |
| **Total waste generation $m^3$ ($ft^3$)** | 0.03 (1)[c] | 0.18 (6.4) | 0.36 (12.7) | 0.72 (25.4)[d] |
| **Unitized ($m^3/m^2$)** | 0.003 | | | 0.07 |

a Total for all decontamination cycles conducted during the demonstration
b Extrapolated
c Surface Area Decontaminated = 11.1 $m^2$ (119 $ft^2$)
d Surface Area Assumed Decontaminated = 2 x 5.1 $m^2$ = 10.2 $m^2$ (110 $ft^2$)

**Table 5. Waste Stream Descriptions and Quantities**

The objectives of this demonstration were listed earlier in this section. The following discusses how the EAI technology met those objectives.

**Improved Decontamination Performance**

Figure 7 provides a graph that illustrates a comparison of the innovative and baseline techniques described in this ITSR. The innovative EAI technology was more effective on the initial decontamination cycle and overall performance than decontamination with the baseline nitric acid wipe technology.

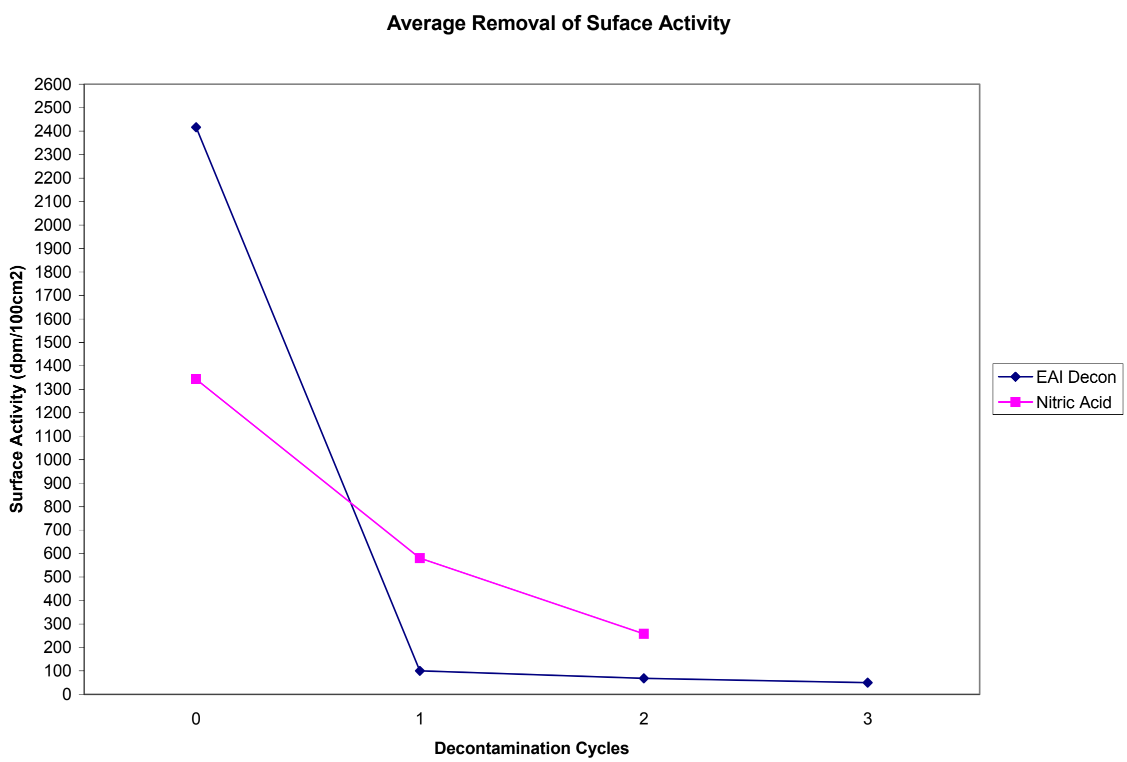


**Figure 7. Comparison of Average Surface Activity Results for the EAI Technology and Nitric Acid**

**Improved Feasibility**

The EAI technology is feasible and comparable to the nitric acid baseline technique. Two specific process problems using the EAI decontamination technology need resolution:

1. The 0100 solution makes the spray bottle and scrub stick slippery when using gloves. This made scrubbing difficult and time was lost retrieving material from the bottom of the box. The second problem occurred during both the innovative technology and baseline demonstrations. This was the difficulty of physically reaching all interior surfaces. Further experimentation is needed to perfect the mechanical means (extension sticks, grippers, etc.) of reaching all interior surfaces with enough leverage to apply scrubbing force.

2. The technicians reported that the rinsing and drying process is work intensive and fatiguing. Therefore, they recommend alternating individual workers between tasks such as rinsing and wiping.

As can be seen from the data in Table 4, the time required for three applications of the innovative technology is only slightly higher than four applications of the baseline technology. Mobilization and demobilization requirements were essentially the same.

**Safety**

The EAI solutions are less hazardous than the nitric acid baseline solution, but since the work was done in a glovebox, this added feature is of limited value. Table 4 compares the time associated with each of the activities necessary to complete decontamination with each technique. The slightly higher glovebox work-time of the EAI technology decontamination increases the exposure time for the technicians.

**Waste Generation Minimization**

The baseline technology produced 0.18 $m^3$ (6.36 $ft^3$) of contaminated polypropylene rags (solid waste) as a result of wiping down the one half of the glovebox surfaces twice. To account for the wiping the entire glovebox, this quantity must be doubled to 0.36 $m^3$ (12.7 $ft^3$). It is assumed that the entire glovebox would need to be wiped the equivalent of two more times. This would result in the generation of waste rags estimated to total 0.72 $m^3$ (25.4 $ft^3$).

**Cost Effectiveness**

Section 5 and Appendix C of this report document a cost comparison of the two decontamination technologies. Although the innovative technology proved to be slightly more costly, efficiencies gained through performing decontamination of multiple gloveboxes would reverse this relationship.

SECTION 4
# TECHNOLOGY APPLICABILITY AND ALTERNATIVES

## Technology Applicability

The EAI chemical extraction technology is designed to work well on any porous surface, ranging from those with a great number of capillary channels or "breathable veins" to those with a small number of very "light" capillaries. Specific types of surfaces and substrates where the extraction process is reported by the EAI to be effective include:

- Concrete
- Brick, cinder block, and red tile
- Asphalt
- Transite
- Wood
- Cost iron and other metals
- Steel and stainless steel
- Exotic metals

Note: It is anticipated that solution components, application order, and work/waiting times will vary according to both the material to be cleaned and the extent of contamination encountered.

## Competing Technologies

- **<u>$CO_2$ Pellet Process</u>** – A process that utilizes small, solid carbon dioxide particles propelled by dry compressed air. The $CO_2$ particles shatter upon impact with a surface and flash into dry $CO_2$ gas. Decontamination is accomplished when the $CO_2$ particles shatter upon impact with the surface and flash dry into $CO_2$ gas. The rapidly expanding $CO_2$ gas lifts and flushes the contamination. Contamination and materials are then either captured by a HEPA filter or removed using HEPA-filtered vacuum cleaners. Advantages include:

    1. Time ~ 4 hours (1.2 m (4 ft.) x 1.2 m (4 ft.) x 0.9 m (3 ft.) glovebox)
    2. No Secondary Waste
    3. No scrubbing (not labor intensive)
    4. Minimizes radiation exposure to workers
    5. Reliable technology, but only good for removable contamination. Unlikely to meet the decontamination goals.

- **<u>High Pressure Water Process</u>** – Consists of a high-pressure water pump and a specially made gun-type water jet-cleaning tool. All moving parts are enclosed within removable protective covers for operator safety. An eleven horse power electric motor along with a triplex pump is used to achieve and maintain normal working water pressures from 5000- 40,000 psi. Incoming water is dual filtered to remove particles larger than 0.5 microns. Advantages include:

    1. Time ~ 4 hours (1.2 m (4 ft.) x 1.2 m (4 ft.) x 0.9 m (3 ft.) glovebox)
    2. Removes coatings including multiple layers of paint
    3. No scrubbing (not labor intensive)
    4. Minimizes radiation exposure to workers
    5. Reliable technology, but high-pressure safety concerns preclude use at LANL
    6. Patents/Commercialization/Sponsor

SECTION 5
# COST

## Methodology

The objective of the following analysis is to provide interested parties with a cost estimate for implementation of the EAI decontamination technology at a DOE site and a comparison with the currently used method of acid washing. This estimate considers the costs associated with both technologies on a per glovebox basis. In both technologies two workers are present. A Radiation Control Technician (RCT) is needed to introduce materials into the glovebox lines.

The baseline and EAI technologies were demonstrated at LANL under controlled conditions (i.e., an in-place glovebox), which facilitated observation of the work procedures and provided an estimate of the typical duration of the procedures. To approach realistic implementation costs, additional assumptions were invoked regarding the cost comparison with the baseline technology. This cost analysis compares both technologies based on a unit processing cost.

Key assumptions for the cost estimate/cost comparison are listed below. Other assumptions and details about the cost analysis are presented in Appendix C.

- A DOE site, such as LANL, will contract Environmental Alternatives Inc. to decontaminate one glovebox with an inner surface area of approximately 11.1 $m^2$ (119 $ft.^2$).
- To arrive at an implementation cost per glovebox, the time and material costs required to apply each technology were normalized on a per square meter basis.
- The work team consisted of two technicians.
- It is assumed that LANL completed the Hazard Control Plan for this work and proper accommodations were made to accept the EAI decontamination solutions and waste types.
- No overhead factors were applied to other direct costs.
- Fully burdened labor rates for LANL personnel were used in the estimate.
- Gloveboxes are assumed to be free of equipment, and no other cost to clean or move equipment out of the glovebox is included.
- No additional procedural costs were involved.

## Cost Analysis

To develop an estimate for implementation, a cost per glovebox basis was chosen. Activities were grouped under higher level work titles per the work breakdown structure shown in *Hazardous Toxic, Radioactive Waste Remediation Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS) (U.S. Army Corps of Engineers, 1996).

Using the demonstration costs as a basis, estimates were developed for mobilization, sampling and testing, demobilization and disposal costs for the innovative technology and the baseline technology. This resulted in total estimated costs of \$33,353 using the EAI Technology to decontaminate a 11.1 $m^2$ (119 $ft^2$) glovebox and \$29,567 using the nitric acid (baseline) technique to decontaminate a 10.2 $m^2$ (110 $ft^2$) glovebox.

Figure 8 compares the implementation costs for both techniques. The mobilization cost for the EAI technology is greater than that of the nitric acid because of the cost of equipment and EAI technical expertise. The other costs including those for waste disposal are significantly less.

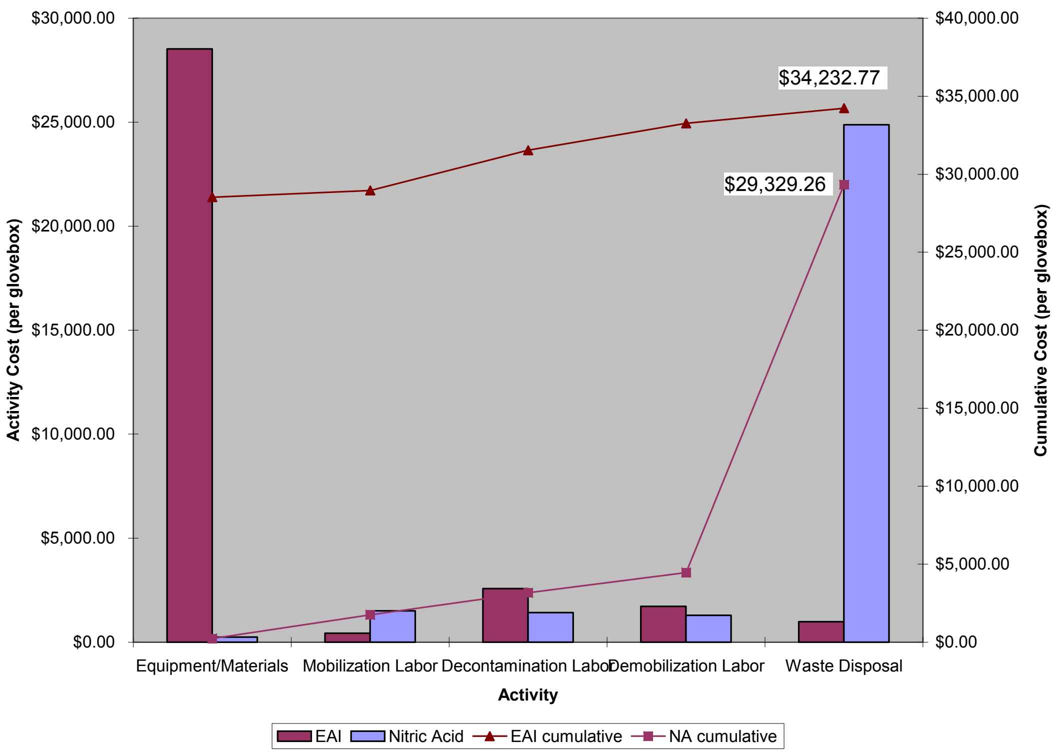


**Figure 8. Glovebox Costs for the EAI Technology and Nitric Acid**

## Cost Conclusions

The cost estimate provides a reasonable cost for implementation of the EAI Decontamination method (Innovative technology) at a DOE site. Using the demonstration costs as a basis, costs were developed for mobilization, sampling and testing, demobilization and disposal costs for the innovative technology and the baseline technology (nitric acid wipe down). In the cost estimate section of this report, it was determined that the cost for the innovative technology is approximately $\$3,095/m^2$ ($\$288/ft^2$), while the cost for the baseline is approximately $\$2,875/m^2$ ($\$267/ft^2$). Therefore, the cost of the baseline technology is approximately 96% that of the innovative technology to achieve same goal. More significantly, the dominant cost of the EAI decontamination estimate is the subcontractor cost, which involved two weeks of subcontractor support time for this single glovebox. In reality, two or more gloveboxes could have been decontaminated in this time period. If two 10.2 $m^2$ gloveboxes were decontaminated, the unit cost drops to $\$1,727/m^2$. Therefore, for multiple gloveboxes, the EAI unitized cost would be lower than the baseline cost.

SECTION 6
# REGULATORY AND POLICY ISSUES

## Regulatory Considerations

The chemical formulations used in the technology satisfy OSHA Section SVIII, 29 CFR 191.1200, as containing no hazardous components regarding flammability or reactivity (as per 40 CFR 261). They are carefully designed to prevent the release of any harmful fumes. Even though low and high pH blends are used in the process, the pH at disposal is close to 7, and the liquids are non-corrosive. The solutions do not contain components that would classify them as hazardous for disposal under TCLP testing. As a result, the waste stream from a project can be characterized as TRU waste based on the contaminants extracted. The Environmental Alternatives Inc. decontamination solutions are developed and patented by EAI. No permits were required to demonstrate the EAI decontamination system at LANL.

## Safety, Risks, Benefits, and Community Reaction

### Worker Safety

Operators must be trained in the proper procedures for glovebox work. Since less time is spent working in gloveboxes, worker safety will be improved.

### Community Safety

Community safety is not adversely affected by using the EAI Decontamination method. Use of the EAI solutions does affect the background radiation in an area. Transportation of the solutions to the cleaning site poses no risk to the public. Disposal of the used solutions follows the approved pathway for TRU waste.

### Environmental Impact

There is no negative impact and a potential positive impact because using the EAI technology has the capability to dramatically reduce contamination levels within gloveboxes so that they may be reused. If not suitable for reuse, gloveboxes may be disposed of according to the level of their remaining contamination, generally as LLW.

### Socioeconomic Impacts and Community Reaction

There are no socio-economic impacts associated with the EAI Decontamination method. Community reaction, while unknown at this time, is likely to be positive since less actinide waste will be disposed of.

SECTION 7
# LESSONS LEARNED

## Implementation Considerations

The EAI Decontamination solutions, training and operating support are available for use at other DOE sites. The following should be considered when selecting the EAI decontamination system as a decontamination technology. Our demonstration showed positive results on decontaminating one particular glovebox. No two gloveboxes can be expected to have the same level or makeup of contamination, so results may vary. More experience is required before one can reach a general conclusion on the validity of this process.

- The site using the EAI Decontamination System must have TRU waste disposal capabilities for rags.
- Because the decontamination process can be strenuous, only workers in good health should be used.
- It is important to use many rags to prevent contaminants from spreading to previously decontaminated areas.

## Technology Limitations and Needs for Future Development

The EAI Decontamination process demonstration conclusively proved that it successfully decontaminated the test glovebox. It provides DOE a simple means of reducing contamination levels within gloveboxes so that they can be reused or disposed of. The technicians had the following comments and recommendations regarding the ergonomics of using this process within a glovebox.

- A dry run should be performed with the tools that will be used. It is important that a means is provided to reach all glovebox surfaces with the abrasive pad.
- The tools should have grips or a non-slip wrap to prevent them from sliding out of the gloves.
- Spray bottles should be used that can be sprayed while in the horizontal position.
- The glovebox surfaces, including the gloves and doors will become sticky when left overnight. One should insure that all surfaces are rinsed thoroughly before stopping work overnight.
- A wet vacuum could be used to speed up the rinsing and drying process, although this will substantially increase the waste volume to be disposed of.
- Recommend checking the spray bottles before introducing them into the glovebox since they may become clogged.
- Alpha probe should be protected while not in use.

APPENDIX A
# REFERENCES


U.S. Army Corps of Engineers (USACE), *Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure*, Prepared for the U.S. Department of Energy, draft January 1996.

IT Corporation, 2002, *Test Plan for the EAI Decontamination Technology*.

## APPENDIX B
## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| $cm^2$ | square centimeters |
| D&D | Decontamination and Decommissioning |
| DDFA | Deactivation and Decommissioning Focus Area |
| DF | decontamination factor |
| DOE | U.S. Department of Energy |
| EAI | Environmental Alternatives, Inc. |
| $ft^2$ | square feet |
| $ft^3$ | cubic feet |
| HTRW RA WBS | Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure |
| in | inch |
| ITSR | Innovative Technology Summary Report |
| kdpm | kilodisintegrations per minute |
| L | liter(s) |
| LANL | Los Alamos National Laboratory |
| LLW | Low Level Waste |
| LSDDP | Large-scale Demonstration and Deployment Project |
| $m^2$ | square meters |
| $m^3$ | cubic meters |
| mL | milliliters |
| N | normal |
| OST | Office of Science and Technology |
| TA | Technical Area |
| TMS | Technical Management System |
| TRU | transuranic |

# APPENDIX C
# TECHNOLOGY COST COMPARISON

## Basis of Estimated Cost

The activity titles shown in this cost analysis for implementation were derived from observation of the work performed and from a reasonable estimate of the level of effort required for implementation at other DOE sites. In the estimate the activities are grouped under higher-level work titles according to the work breakdown structure shown in the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS) (U.S. Army Corps of Engineers, 1996). The HTRW RA WBS was developed by an interagency group, and is used in this analysis to provide consistency with the established national standards.

The costs shown in this analysis are computed from observed duration and hourly rates for the crew, supplies, and equipment.

## Activity Descriptions

**Mobilization and Preparatory Work (WBS 33.1.01)**

***Mobilization of Equipment***

<u>Innovative Technology</u>

The EAI chemical solutions and technical consulting costs charged for this demonstration are included in the Mobilization section of the cost estimate (Table C-1) and are used in this analysis. The proposal provided for two weeks of technical consulting, all solutions needed to decontaminate the glovebox. This cost was based on contamination levels and isotopic assay provided beforehand. This cost was $28,525. This cost, in entirety, was applied to the decontamination of the single glovebox. In reality, two weeks of EAI support could have accomplished decontamination of at least two gloveboxes.

<u>Baseline Technology</u>

The cost of nitric acid solution used for the baseline demonstration was approximately $100 per gallon. In the demonstration, a portion of 1 L of solution was used for the demonstration on ½ of the glovebox (two decontamination cycles), which would result in using approximately 3 L for four decontamination cycles on the entire glovebox. The cost of polypropylene rags for 80 bags of rags was approximately $160. It is apparent that material costs for the baseline technology are significantly lower than those for the EAI contract. The total material cost for each glovebox is approximately $236.

*Mobilization of Personnel* – Per LANL procedures (two-man rule), two technicians are required to introduce the equipment into the glovebox line. It is assumed that any site implementing these technologies will have similar requirements. For this cost estimate, it was assumed that mobilization begins at the glovebox entry point where the solution bottles and polypropylene rags are introduced into the glovebox.

*Submittals/Implementation Plans* – Plans and permits were assumed to be complete prior to the start of work and will not be considered in this cost estimate.

**Monitoring, Sampling & Testing (WBS 33.1.02)**

The cost estimate for this WBS element included 2 technicians to conduct decontamination operations for both the innovative and baseline techniques. Table 4 shows the recorded times for each activity associated with the demonstration. It also provides total extrapolated times for decontamination of the entire glovebox surface (10.2 $m^2$ or 110 $ft^2$) using nitric acid.

The results presented in Table 2, show that the baseline technology did not reduce contamination levels on all surfaces below the target 50,000 dpm/100 $cm^2$ after two decontamination passes on the walls and ceilings. It was assumed in this cost estimate that the equivalent of two more passes, for the whole glovebox, could achieve the decontamination goal of 50,000 dpm/100 $cm^2$.

The application times for the baseline technology were approximately 1/2 hour for the initial pass followed by 20 minutes (0.33 hour) to survey the surfaces. Although the second pass took longer to decontaminate but less to survey, it is assumed that over four cycles work efficiency would achieve approximate the same work-rate as the initial pass. To adjust these times to the entire surface area, the times were doubled. Since a total of four passes are assumed, the total times were estimated as shown in Table 4.

**Decontamination (WBS 33.1.02)**

Equipment Decontamination and Release – For this estimate it is assumed that equipment inside the glovebox will be packaged and disposed of rather than decontaminated.

**Waste Disposal (WBS 33.1.18)**

Table 5 shows quantities of waste generated during the demonstration. This table provides the quantity of waste generated during the demonstration and estimates a waste quantity for an entire glovebox of 10.2 $m^2$ (110 $ft^2$) using the nitric acid technique.

According to the LANL 2000 Waste Recharge Rates, the cost of TRU waste is \$34,550/$m^3$ (\$978/$ft^3$).

The baseline technology produced approximately 0.18 $m^3$ (6.4 $ft^3$) of waste during the demonstration for one-half of the glovebox. For this cost estimate, the waste volume was estimated at approximately 0.72 $m^3$ (25.4 $ft^3$) of TRU waste during decontaminating of the entire glovebox. For a glovebox with a surface area of 10.2 $m^2$ (110 $ft^2$), the cost to dispose of this waste would be \$24,876 per glovebox.

## Cost Estimate Summary

The cost analysis details are summarized in Tables C-1 and C-2. The tables break out each activity, labor rate, and piece of equipment used. Table C-2 extrapolates the cost to the entire 10.2 $m^2$ (110 $ft^2$) glovebox.

### Table C-1. EAI Technology Implementation Costs

| | Labor | Materials | Labor Qty | Units | Unit Cost | Qty | Subtotal |
|---|---|---|---|---|---|---|---|
| **Mobilization and Preparatory Work** | | | | | | | **$28,955.00** |
| *Materials* | | | | | | | *$28,525.00* |
| | | Onsite consultant | | Lump | $25,650.0 | 1 | $25,650.00 |
| | | Roundtrip (mob/de) | | Lump | $2875.00 | 1 | $2,875.00 |
| *Labor* | | | | | | | *$430.00* |
| | Initial glovebox survey | | 2 | Hour | $107.5 | 1 | $215.00 |
| | Load materials into glovebox | | 2 | Hour | $107.5 | 1 | $215.00 |
| **Monitoring, Sampling & Testing** | | | | | | | **$2,580.00** |
| *Labor* | | | | | | | *$2580.00* |
| | Apply and scrub | | 2 | Hour | $107.5 | 4 | $860.00 |
| | Dry and Polish | | 2 | Hour | $107.5 | 5 | $1,075.00 |
| | Survey | | 2 | Hour | $107.5 | 3 | $645.00 |
| **Demobilization** | | | | | | | **$2,697.77** |
| *Labor* | | | | | | | *$1,720.00* |
| | Waste packaging | | 2 | Hour | $107.5 | 8 | $1,720.00 |
| *Waste Disposal* | | | | | | | *$977.77* |
| | | Disposal cost | | $m^3$ | $34,550 | 0.03 | *$977.77* |
| | | | | | | **TOTAL** | **$34,232.77** |
| | | | | | | **$/m$^2$** | **$3095.19** |

### Table C-2. Nitric Acid Implementation Costs

| | Labor | Materials | Labor Qty | Units | Unit Cost | Qty | Subtotal |
|---|---|---|---|---|---|---|---|
| **Mobilization and Preparatory Work** | | | | | | | **$1,744.26** |
| *Materials* | | | | | | | *$236.26* |
| | | 0.5N nitric acid | | Liter | $26.42 | 3 | *79.26* |
| | | Rags | | Bag | $2.00 | 80 | *$160.00* |
| *Labor* | | | | | | | *$1505.00* |
| | Initial glovebox survey | | 2 | Hour | $107.50 | 1 | *$215.00* |
| | Load materials into glovebox | | 2 | Hour | $107.50 | 6 | *$1290.00* |
| **Monitoring, Sampling & Testing** | | | | | | | **$1,419.00** |
| *Labor* | | | | | | | *$1,419.00* |
| | Apply and scrub | | 2 | Hour | $107.50 | 2 | *$430.00* |
| | Dry and Polish | | 2 | Hour | $107.50 | 2 | *$430.00* |
| | Survey | | 2 | Hour | $107.50 | 2.6 | *$559.00* |
| **Demobilization** | | | | | | | **$26,166.00** |
| *Labor* | | | | | | | *$1,290.00* |
| | Waste packaging | | 2 | Hour | $107.50 | 6 | *$1,290.00* |
| *Waste Disposal* | | | | | | | *$24,876.00* |
| | | Disposal cost | | $m^3$ | $34,550 | 0.72 | *$24,876.00* |
| | | | | | | **TOTAL** | **$29,329.26** |
| | | | | | | **$/m$^2$** | **$2,875.42** |

# APPENDIX D
# RAW DATA

## Table D-1. Initial and Final Surface Activity Data Collected During the EAI Demonstration

| # | Glovebox Surface | Initial Surface Activity (cpm) | Cycle 1 Surface Activity (cpm) | Cycle 2 Surface Activity (cpm) | Cycle 3 Surface Activity (cpm) |
|---|---|---|---|---|---|
| 1 | Air background | 10 | 0.75 | 0.25 | |
| | | | | | |
| | ***Floor*** | | | | |
| 2 | Left Floor Back | 1000 | 35 | 25 | |
| 3 | Left Floor Front | 1000 | 100 | 15 | |
| 4 | Center Floor Back | 1000 | 75 | 55 | |
| 5 | Center Floor Front | 1000 | 100 | 90 | |
| 6 | Right Floor Back | 1000 | 20 | 22 | ND |
| 7 | Right Floor Front | 1000 | 100 | 75 | 2 |
| | | | | | |
| | ***Walls*** | | | | |
| 8 | Left Wall | 1000 | 20 | 5 | |
| 9 | Right Wall | 1000 | 60 | 12.5 | |
| 10 | Left Wall Front | 1000 | 25 | 20 | |
| 11 | Center Wall Front | 1000 | 35 | 22 | |
| 12 | Right Wall Front | 1000 | 35 | 12.5 | |
| 13 | Left Wall Back | 950 | 7.5 | | |
| 14 | Center Wall Back | 300 | 15 | 10 | |
| 15 | Right Wall Back | 750 | 15 | 8 | |
| 16 | Center Shelf | 1000 | 75 | 55 | |
| 17 | Left Shelf | 1000 | 75 | 30 | |
| 18 | Right Shelf | 1000 | 65 | 30 | |
| | | | | | |
| | ***Windows*** | | | | |
| 19 | Left Window | 1 | 6 | 10 | |
| 20 | Center Window | 200 | 6 | 5 | |
| 21 | Right Window | 75 | 4.5 | 3.5 | |
| 22 | Upper Left Window | 1000 | 10 | | |
| 23 | Upper Center Window | 1000 | 10 | | |
| 24 | Upper Right Window | 1000 | 15 | | |
| 25 | Lower Left Window | 1000 | 35 | | |
| 26 | Lower Center Window | 1000 | 20 | | |
| 27 | Lower Right Window | 1000 | 4 | | |
| | | | | | |
| | ***Ceiling*** | | | | |
| 28 | Left Ceiling | 950 | 20 | | |
| 29 | Center Ceiling | 300 | 15 | | |
| 30 | Right Ceiling | 750 | 15 | | |

## Table D-2
## Activity/Time Record

| Task | Start A.M | Finish A.M | Start A.M. | Finish P.M. | TOTAL |
|---|---|---|---|---|---|
| | | | | | |
| ***Wednesday September 11*** | | | | | |
| Survey glovebox | 11:20 | 12:00 | | | 0:40 |
| Spray on 0100 solution | | | 2:40 | 2:50 | 0:10 |
| Sprayed on rinsate solution | | | 3:05 | 3:10 | 0:05 |
| Squeegee and dry surfaces on 1/3 GB | | | 3:10 | 3:50 | 0:40 |
| Spray rinsate for remaining 2/3 of GB | | | 3:50 | 4:10 | 0:20 |
| Squeegee and dry surfaces on remaining GB | | | 4:10 | 5:15 | 1:05 |
| **Daily Total** | | | | | **3:00** |
| | | | | | |
| ***Thursday September 12*** | | | | | |
| Spray down surfaces with 0200/0300 | 8:35 | 8:58 | | | 0:23 |
| Introduce more rinse solution into glovebox | 8:58 | 9:15 | | | 0:17 |
| Finish rinsing and drying glovebox surfaces | 9:15 | 10:27 | | | 1:12 |
| Applying 0300 solution and scrub | 10:30 | 11:16 | | | 0:46 |
| Introduce rinse into glovebox | 11:20 | 11:30 | | | 0:10 |
| Squeegee and drying surfaces | 11:40 | 12:15 | | | 0:35 |
| Introduce new probe | | | 2:50 | 3:00 | 0:10 |
| Survey GB 262 surfaces | | | 3:00 | 4:35 | 1:35 |
| **Daily Total** | | | | | **5:08** |
| | | | | | |
| ***Tuesday September 17*** | | | | | |
| Introduced more rinse solution in GB262 | 10:50 | 11:05 | | | 0:15 |
| Sprayed down GB262 with 0100, and scrub | 11:06 | 11:40 | | | 0:34 |
| Load new rags into GB262 | | | 2:15 | 2:30 | 0:15 |
| Sprayed on rinsate solution and scrub | | | 2:30 | 2:35 | 0:05 |
| Rinsed and dried glovebox surfaces | | | 2:45 | 3:20 | 0:35 |
| **Daily Total** | | | | | **1:44** |
| | | | | | |
| ***Wednesday September 18*** | | | | | |
| Polished GB 262 surfaces | 9:15 | 10:05 | | | 0:50 |
| Survey GB 262 surfaces | 10:05 | 10:45 | | | 0:40 |
| Applied 0100 solution to 2 hot spots in front of windows | 10:45 | 10:55 | | | 0:10 |
| Finish rinsing and drying glovebox surfaces | | | 12:45 | 1:30 | 0:00 |
| Applied 0200/0300 solution | | | 1:30 | 1:35 | 0:05 |
| **Daily Total** | | | | | **1:45** |
| | | | | | |
| ***Thursday September 19*** | | | | | |
| Applied rinsate solution and dried surfaces | | | 9:40 | 10:25 | 0:45 |
| Survey GB 262 surfaces | | | 10:25 | 10:35 | 0:10 |
| | | | | | |
| **Daily Total** | | | | | **0:55** |
| **Grand Total Time** | | | | | **12:32** |